REMARKS

The subject invention relates to optical measurement techniques used in the fabrication of a semiconductor wafer. As discussed in the specification, for example in conjunction with Figure 5, it is often desirable to monitor wafer characteristics at various stages of the fabrication process. In one example, the wafer can be measured after the photoresist has been applied. Assuming the wafer passes the inspection, it is supplied to an etch tool. After the etching step, the wafer can then be measured a second time to determine if the parameters are still within a preselected criteria.

In many current applications, it is not possible to determine a wafer's physical characteristics (layer thickness, index of refraction, etc.) by direct calculation from the measured light intensities. Rather, it is necessary to create a theoretical model of the sample which includes the expected physical structure. Next, a series of theoretical parameters are generated corresponding to possible expected parameters. Using well known equations (such as Maxwell's equations), a set of intensity signatures, corresponding to theoretical measurements are calculated by applying the various theoretical parameters to the model. These calculations can be performed in advance so that a library of signatures are generated and stored. Alternatively, the signature generation can be performed iteratively, in real time. In either case, the signatures are compared to the actual measured intensities to obtain a best match. The theoretical parameters associated with the best match signature are assumed to be the actual parameters of the measured target.

The above described process can be complex, particularly when the number of unknown parameters becomes quite large. For example, in a structure as shown in Figure 3 and 4, there are multiple layers. Each layer can have an unknown thickness, index of refraction and extinction coefficient. Further unknowns include line spacing and line shape. All of these variables must be accounted for in the process.

The subject invention is intended to reduce some of these complexities in the measurement process. More specifically, and as defined in new independent claim 36, the wafer is measured after a first fabrication step. The parameters of the measured feature are determined by comparing the optical measurements to theoretical optical results (signatures) calculated from a first model using a set of first theoretical parameters. The results might include, for example, the actual thickness, index of refraction and extinction coefficient of the first oxide layer.

The wafer is then subjected to a second process step, for example, the deposition of an ARC layer. A second measurement of the wafer is then taken. The parameters of the sample at this stage of the fabrication process are again determined by comparing the optical measurements to theoretical results (signatures) calculated from a second model (corresponding to the wafer with the added layer).

The signatures generated using the second model are based on a set of second theoretical parameters. In addition, and in accordance with the subject invention, the parameters used to generate the second signatures include at least one of the first parameters determined from the first measurement. For example, the calculations of the second signatures might include the actual thickness of the oxide layer, determined from the first measurement. The actual thickness is therefore used as a fixed parameter rather than as a variable parameter. By reducing one or more variables for the signature calculations, the analysis can be simplified. It should be noted that such a simplification is often warranted since the thickness of the oxide layer will typically not change simply because an ARC layer has been deposited thereon.

In the Office Action, the Examiner rejected the main claims based the patent to Engelhard (6,791,679). In response to the rejection, Applicants have cancelled the original claims and substituted therefore new independent claim 36 to better distinguish the invention over Engelhard. New dependent claims 37 to 45 correspond substantially to original claims 3, 4 and 8 to 14.

The patent to Engelhard describes making measurements on a wafer at two separate stages during the fabrication process. Engelhard defines the first stage as the develop inspect (DI) stage to obtain a DI profile. The second stage occurs later in the process and is defined as the final stage (FI) measurement to obtain an final FI profile. Prior to inspection, Engelhard creates libraries of signatures corresponding to both measurement phases. The library of D1 signatures is created in the same manner as discussed above. More specifically, a model is created corresponding the expected structure. Various theoretical parameters are fed to the model and signatures are generated to create a library. In one embodiment, Engelhard generates the F1 signatures in the same fashion, by feeding theoretical parameters to a model associated with the F1 state.

After the libraries are created, test wafers are measured. The wafers are first measured at the D1 stage and the actual parameters are determined by reference to the library of signatures.

The test wafers are then measured at the F1 stage and the actual parameters of the wafers are determined by reference to the F1 library of signatures. At this point, correlation tables are generated comparing actual DI profiles with actual F1 profiles. In other words, Engelhard attempts to establish what the possible F1 profiles will look like when starting from any given D1 profile. These correlations can be updated with future data.

Claim 36 differentiates from the Engelhard process by the manner in which it determines the actual sample parameters after the second measurement. More specifically, in Engelhard, the actual parameters determined after the second measurement are calculated by reference to the F1 library, which was generated wholly with theoretical data. Engelhard's F1 library does not contain any information about actual parameters obtained during his first measurement. In contrast, claim 36 specifies that the second parameters from the second measurement are determined by comparing the second optical measurement:

> "...to theoretical optical results calculated from a second theoretical model of the wafer using a second set of theoretical parameters **in combination with at least one of the previously determined first parameters used as a fixed parameter thereby reducing the number of fitting parameters needed to determine the second parameters**."

This concept is simply not taught anywhere in Engelhard. As noted by the Examiner, Engelhard does use the actual measurements made during the first measurement to predict what the second measurements should look like. However, these predictions are only that, predictions, not real results. Engelhard compares the real second measurements to the predicted measurements only to see if there are any deviations from expected performance. As noted, the real second parameters are determined by comparing the optical measurements to the F1 library created from theoretical parameters, not any parameters actually determined during the first measurement.

The Examiner also notes that if the difference between the expected results and the actual results differ, Engelhard will update the correlation. However, this still does not mean that the actual determination of the parameters made after the second measurement is based upon any actual parameters determined during the first measurement since the F1 signature table is not changed, only the correlation information which helps predict if the results of the actual measurement are reasonable and within the process parameters.

Engelhard discloses one variant to the above described process. In the embodiment associated with Figure 3C, after the D1 library is created, a software program is used to predict theoretical parameters that would result at the F1 stage based on the D1 parameters (see, Engelhard, column 7, line 34+). These theoretical calculated parameters are used to generate the F1 signature library. Even in this embodiment, however, it is clear that the F1 signature library is not based on any parameter determined during the first measurement.

In view of the above, it is respectfully submitted that new independent claim 36 is not anticipated nor rendered obvious by Engelhard.

In the Office Action, the Examiner cited the patent to Bruggerman (6,054,710) for its teaching of a three-dimensional characterization of semiconductor features. The Examiner cited the patent to Piwonka-Corle (5,608,526) for its teaching of broadband spectroscopy. Neither of these references is related to the subject matter of new independent claim 36 and therefore fail to overcome the deficiencies of Engelhard in rendering obvious applicants' invention.

In the Office Action, the Examiner cited the patent to Krishnan (6,710,890) for its teaching of first and second metrology tools. Krishnan relates to a metrology device for measuring wafer substrate thickness. The tool includes a platen 12 upon which the substrate 14 to be measured rests. In addition, the platen supports a reference 20 having a known thickness. In one embodiment, a first sensor 22 is positioned to measure the thickness of the reference and a second sensor 24 is positioned to measure the thickness of the substrate.

Krishnan differs from the subject invention in many respects. First, there is no disclosure of measurements made both before and after a specific fabrication step where the character of the wafer will be changed. More importantly, Krishnan relates to measurements of two different targets, a reference and the actual substrate. In applicants' invention, the intent is to take the first and second measurement at the same location on the sample so that a parameter at that location determined during the first measurement can be used as a fixed, known parameter in evaluating the second measurement. For these reasons, it is submitted that the patent to Krishnan cannot overcome the deficiencies of the primary references in rendering obvious applicants' invention.

In view of the above, it is respectfully submitted that independent claim 36 defines patentable subject matter and allowance thereof, along with the claims depending therefrom is respectfully solicited.

Respectfully submitted,

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Dated: February 21, 2006

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